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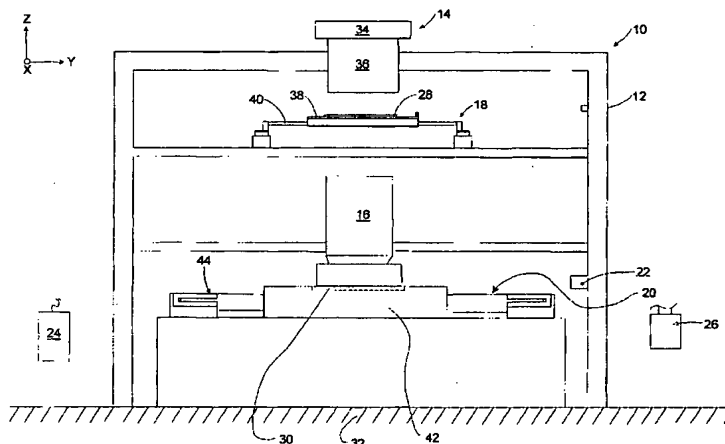
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(54) Title: APPARATUS AND METHOD FOR MAINTAINING IMMERSION FLUID IN THE GAP UNDER THE PROJECTION LENS DURING WAFER EXCHANGE IN AN IMMERSION LITHOGRAPHY MACHINE



(57) Abstract: An apparatus and method for maintaining immersion fluid (212) in the gap adjacent the projection lens (16) during the exchange of a work piece (208) in a lithography machine (10) is disclosed. The apparatus and method includes an optical assembly (16) configured to project an image onto a work piece (208) and a stage assembly (202) including a work piece table (204) configured to support the work piece (208) adjacent the optical assembly (16). An environmental system (26) is provided to supply and remove an immersion fluid (212) from a gap between the optical assembly (16) and the work piece (208) on the stage assembly (202). After exposure of the work piece (208) is complete, an exchange system (216) removes the work piece (208) and replaces it with a second work piece. An immersion fluid containment system (214) is provided to maintain the immersion liquid (212) in the gap during removal of the first work piece (208) and replacement with the second work piece.

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# APPARATUS AND METHOD FOR

# MAINTAINING IMMERSION FLUID IN THE GAP UNDER THE PROJECTION LENS DURING WAFER EXCHANGE IN AN IMMERSION LITHOGRAPHY MACHINE

## RELATED APPLICATIONS

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repeated until all the dice on the wafer are exposed. The wafer is then removed and a new wafer is exchanged in its place.

Immersion lithography systems utilize a layer of immersion fluid that completely fills a gap between the optical assembly and the wafer during the exposure of the wafer. The optic properties of the immersion fluid, along with the optical assembly, allow the projection of smaller feature sizes than is currently possible using standard optical lithography. For example, immersion lithography is currently being considered for next generation semiconductor technologies including 65 nanometers, 45 nanometers, and beyond. Immersion lithography therefore represents a significant technological breakthrough that will likely enable the continued use of optical lithography for the foreseeable future.

After a wafer is exposed, it is removed and exchanged with a new wafer. As currently contemplated in immersion systems, the immersion fluid would be removed from the gap and then replenished after the wafer is exchanged. More specifically, when a wafer is to be exchanged, the fluid supply to the gap is turned off, the fluid is removed from the gap (i.e., by vacuum), the old wafer is removed, a new wafer is aligned and placed under the optical assembly, and then the gap is re-filled with fresh immersion fluid. Once all of the above steps are complete, exposure of the new wafer can begin.

Wafer exchange with immersion lithography as described above is problematic for a number of reasons. The repeated filling and draining of the gap may cause variations in the immersion fluid and may cause bubbles to form within the immersion fluid. Bubbles and the unsteady fluid may interfere with the projection of the image on the reticle onto the wafer, thereby reducing yields. The overall process also involves many steps and is time consuming, which reduces the overall throughput of the machine.

An apparatus and method for maintaining immersion fluid in the gap adjacent the projection lens when the wafer stage moves away from the projection lens, for example during wafer exchange, is therefore needed.

## SUMMARY

An apparatus and method for maintaining immersion fluid in the gap adjacent the projection lens in a lithography machine is disclosed. The apparatus

and method includes an optical assembly configured to project an image onto a work piece and a stage assembly including a work piece table configured to support the work piece adjacent the optical assembly. An environmental system is provided to supply and remove an immersion fluid from the gap. After exposure of the work piece is complete, an exchange system removes the work piece and replaces it with a second work piece. An immersion fluid system is provided to maintain the immersion fluid in the gap when the work piece table moves away from the projection lens. The gap therefore does not have to be refilled with immersion fluid when the first work piece is replaced with a second work piece.

### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an illustration of an lithography machine having features of the present invention;

Figure 2 is a cross section of an immersion lithography machine according to one embodiment of the present invention;

Figure 3A and 3B are a cross section and a top down view of an immersion lithography machine according to another embodiment of the present invention;

Figure 4A and 4B a cross section and a top down view of an immersion lithography machine according to another embodiment of the present invention;

Figure 5A and 5B are top down views of two different twin wafer stages according to other embodiments of the present invention;

Figure 6A is a top down view of a twin stage lithography machine according to another embodiment of the invention;

Figures 6B-6E are a series of diagrams illustrating a wafer exchange according to the present invention.

Figure 7A is a flow chart that outlines a process for manufacturing a work piece in accordance with the present invention; and

Figure 7B is a flow chart that outlines work piece processing in more detail.

Like reference numbers refer to like elements in the drawings.

## DESCRIPTION

Figure 1 is a schematic illustration of a lithography machine 10 having features of the present invention. The lithography machine 10 includes a frame 12, an illumination system 14 (irradiation apparatus), an optical assembly 16, a reticle stage assembly 18, a work piece stage assembly 20, a measurement system 22, a control system 24, and a fluid environmental system 26. The design of the components of the lithography machine 10 can be varied to suit the design requirements of the lithography machine 10.

In one embodiment, the lithography machine 10 is used to transfer a pattern (not shown) of an integrated circuit from a reticle 28 onto a semiconductor wafer 30 (illustrated in phantom). The lithography machine 10 mounts to a mounting base 32, e.g., the ground, a base, or floor or some other supporting structure.

In various embodiments of the invention, the lithography machine 10 can be used as a scanning type photolithography system that exposes the pattern from the reticle 28 onto the wafer 30 with the reticle 28 and the wafer 30 moving synchronously. In a scanning type lithographic machine, the reticle 28 is moved perpendicularly to an optical axis of the optical assembly 16 by the reticle stage assembly 18 and the wafer 30 is moved perpendicularly to the optical axis of the optical assembly 16 by the wafer stage assembly 20. Scanning of the reticle 28 and the wafer 30 occurs while the reticle 28 and the wafer 30 are moving synchronously.

Alternatively, the lithography machine 10 can be a step-and-repeat type photolithography system that exposes the reticle 28 while the reticle 28 and the wafer 30 are stationary. In the step and repeat process, the wafer 30 is in a constant position relative to the reticle 28 and the optical assembly 16 during the exposure of an individual field. Subsequently, between consecutive exposure steps, the wafer 30 is consecutively moved with the wafer stage assembly 20 perpendicularly to the optical axis of the optical assembly 16 so that the next field of the wafer 30 is brought into position relative to the optical assembly 16 and the reticle 28 for exposure. Following this process, the images on the reticle 28 are sequentially exposed onto the fields of the wafer 30, and then the next field of the

wafer 30 is brought into position relative to the optical assembly 16 and the reticle 28.

However, the use of the lithography machine 10 provided herein is not necessarily limited to a photolithography for semiconductor manufacturing. The lithography machine 10, for example, can be used as an LCD photolithography system that exposes a liquid crystal display work piece pattern onto a rectangular glass plate or a photolithography system for manufacturing a thin film magnetic head. Accordingly, the term "work piece" is generically used herein to refer to any device that may be patterned using lithography, such as but not limited to wafers or LCD substrates.

The apparatus frame 12 supports the components of the lithography machine 10. The apparatus frame 12 illustrated in Figure 1 supports the reticle stage assembly 18, the wafer stage assembly 20, the optical assembly 16 and the illumination system 14 above the mounting base 32.

The illumination system 14 includes an illumination source 34 and an illumination optical assembly 36. The illumination source 34 emits a beam (irradiation) of light energy. The illumination optical assembly 36 guides the beam of light energy from the illumination source 34 to the optical assembly 16. The beam illuminates selectively different portions of the reticle 28 and exposes the wafer 30. In Figure 1, the illumination source 34 is illustrated as being supported above the reticle stage assembly 18. Typically, however, the illumination source 34 is secured to one of the sides of the apparatus frame 12 and the energy beam from the illumination source 34 is directed to above the reticle stage assembly 18 with the illumination optical assembly 36.

The illumination source 34 can be a g-line source (436 nm), an i-line source (365 nm), a KrF excimer laser (248 nm), an ArF excimer laser (193 nm) or a F<sub>2</sub> laser (157 nm). Alternatively, the illumination source 34 can generate charged an x-ray.

The optical assembly 16 projects and/or focuses the light passing through the reticle 28 to the wafer 30. Depending upon the design of the lithography machine 10, the optical assembly 16 can magnify or reduce the image illuminated on the reticle 28. The optical assembly 16 need not be limited to a reduction system. It could also be a 1x or greater magnification system.

Also, with an exposure work piece that employs vacuum ultra-violet radiation (VUV) of wavelength 200 nm or lower, use of the catadioptric type optical system can be considered. Examples of the catadioptric type of optical system include the disclosure Japan Patent Application Disclosure No.8-171054  
5 published in the Official Gazette for Laid-Open Patent Applications and its counterpart U.S. Patent No, 5,668,672, as well as Japan Patent Application Disclosure No.10-20195 and its counterpart U.S. Patent No. 5,835,275. In these cases, the reflecting optical work piece can be a catadioptric optical system incorporating a beam splitter and concave mirror. Japan Patent Application  
10 Disclosure No.8-334695 published in the Official Gazette for Laid-Open Patent Applications and its counterpart U.S. Patent No. 5,689,377 as well as Japan Patent Application Disclosure No.10-3039 and its counterpart U.S. Patent Application No. 873,605 (Application Date: 6-12-97) also use a reflecting-refracting type of optical system incorporating a concave mirror, etc., but without a  
15 beam splitter, and can also be employed with this invention. As far as is permitted, the disclosures in the above-mentioned U.S. patents, as well as the Japan patent applications published in the Official Gazette for Laid-Open Patent Applications are incorporated herein by reference.

The reticle stage assembly 18 holds and positions the reticle 28 relative to  
20 the optical assembly 16 and the wafer 30. In one embodiment, the reticle stage assembly 18 includes a reticle stage 38 that retains the reticle 28 and a reticle stage mover assembly 40 that moves and positions the reticle stage 38 and reticle 28.

Each stage mover assembly 40, 44 can move the respective stage 38, 42  
25 with three degrees of freedom, less than three degrees of freedom, or more than three degrees of freedom. For example, in alternative embodiments, each stage mover assembly 40, 44 can move the respective stage 38, 42 with one, two, three, four, five or six degrees of freedom. The reticle stage mover assembly 40 and the work piece stage mover assembly 44 can each include one or more  
30 movers, such as rotary motors, voice coil motors, linear motors utilizing a Lorentz force to generate drive force, electromagnetic movers, planar motors, or some other force movers.

In photolithography systems, when linear motors (see US Patent Numbers 5,623,853 or 5,528,118 and incorporated by reference herein) are used in the

wafer stage assembly or the reticle stage assembly, the linear motors can be either an air levitation type employing air bearings or a magnetic levitation type using Lorentz force or reactance force. Additionally, the stage could move along a guide, or it could be a guideless type stage that uses no guide.

5           Alternatively, one of the stages could be driven by a planar motor, which drives the stage by an electromagnetic force generated by a magnet unit having two-dimensionally arranged magnets and an armature coil unit having two-dimensionally arranged coils in facing positions. With this type of driving system, either the magnet unit or the armature coil unit is connected to the stage base and  
10           the other unit is mounted on the moving plane side of the stage.

          Movement of the stages as described above generates reaction forces that can affect performance of the photolithography system. Reaction forces generated by the wafer (substrate) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in US Patent No.  
15           5,528,100 and published Japanese Patent Application Disclosure No. 8-136475. Additionally, reaction forces generated by the reticle (mask) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in US Patent No. 5,874,820 and published Japanese Patent Application Disclosure No. 8-330224. As far as is permitted, the disclosures in US Patent  
20           Numbers 5,528,100 and 5,874,820 and Japanese Patent Application Disclosure No. 8-330224 are incorporated herein by reference.

          The measurement system 22 monitors movement of the reticle 28 and the wafer 30 relative to the optical assembly 16 or some other reference. With this information, the control system 24 can control the reticle stage assembly 18 to  
25           precisely position the reticle 28 and the work piece stage assembly 20 to precisely position the wafer 30. The design of the measurement system 22 can vary. For example, the measurement system 22 can utilize multiple laser interferometers, encoders, mirrors, and/or other measuring devices.

          The control system 24 receives information from the measurement system  
30           22 and controls the stage mover assemblies 18, 20 to precisely position the reticle 28 and the wafer 30. Additionally, the control system 24 can control the operation of the components of the environmental system 26. The control system 24 can include one or more processors and circuits.



The environmental system 26 controls the environment in a gap (not shown) between the optical assembly 16 and the wafer 30. The gap includes an imaging field. The imaging field includes the area adjacent to the region of the wafer 30 that is being exposed and the area in which the beam of light energy travels between the optical assembly 16 and the wafer 30. With this design, the environmental system 26 can control the environment in the imaging field. The desired environment created and/or controlled in the gap by the environmental system 26 can vary accordingly to the wafer 30 and the design of the rest of the components of the lithography machine 10, including the illumination system 14. For example, the desired controlled environment can be a fluid such as water. Alternatively, the desired controlled environment can be another type of fluid such as a gas. In various embodiments, the gap may range from 0.1mm to 10mm in height between top surface of the wafer 30 and the last optical element of the optical assembly 16.

In one embodiment, the environmental system 26 fills the imaging field and the rest of the gap with an immersion fluid. The design of the environmental system 26 and the components of the environmental system 26 can be varied. In different embodiments, the environmental system 26 delivers and/or injects immersion fluid into the gap using spray nozzles, electro-kinetic sponges, porous materials, etc. and removes the fluid from the gap using vacuum pumps, sponges, and the like. The design of the environmental system 26 can vary. For example, it can inject the immersion fluid at one or more locations at or near the gap. Further, the immersion fluid system can assist in removing and/or scavenging the immersion fluid at one or more locations at or near the work piece 30, the gap and/or the edge of the optical assembly 16. For additional details on various environmental systems, see Provisional US applications 60/462,142 entitled "Immersion Lithography Fluid Control System" filed on April 9, 2003, 60/462,112 entitled "Vacuum Ring System and Wick Ring System for Immersion Lithography" filed on April 10, 2003, 60/500,312 entitled "Noiseless Fluid Recovery With Porous Material" filed on September 3, 2003, and 60/541,329 entitled "Nozzle Design for Immersion Lithography" filed on February 2, 2004, all incorporated by reference herein.

Referring to Figure 2, a cross section of a lithography machine illustrating one embodiment of the present invention is shown. The lithography machine 200

includes a optical assembly 16 and a stage assembly 202 that includes a wafer table 204 and a wafer stage 206. The wafer table 204 is configured to support a wafer 208 (or any other type of work piece) under the optical assembly 16. An environmental system 26, surrounding the optical assembly 16, is used to supply and remove immersion fluid 212 from the gap between the wafer 208 and the last optical element of the optical assembly 16. A work piece exchange system 216, including a wafer loader 218 (i.e., a robot) and an alignment tool 220 (i.e., a microscope and CCD camera), is configured to remove the wafer 208 on the wafer table 204 and replace it with a second wafer. This is typically accomplished using the wafer loader 218 to lift and remove the wafer 208 from the wafer table 204. Subsequently, the second wafer (not shown) is placed onto the wafer chuck 218, aligned using the alignment tool 220, and then positioned under the optical assembly 16 on the wafer table 204.

With this embodiment, the wafer stage 206 includes an immersion fluid containment system 214 that is configured to maintain the immersion fluid 212 in the gap adjacent the last optical element of the optical assembly 16 during wafer exchange. The immersion fluid containment system 214 includes a pad 222 that is adjacent the wafer table 204. A support member 224, provided between the pad 222 and the wafer stage 206, is used to support the pad 222. The wafer table 204 has a flat upper surface which is coplanar with a surface of the wafer 208. The pad 222 also has a flat upper surface which is coplanar with the upper surface of the wafer table 204 and the wafer surface. The pad 222 is arranged adjacent the wafer table 204 with a very small gap (e.g. 0.1-1.0mm) so that the immersion fluid 212 is movable between the wafer table 204 and the pad 222 without leaking. During a wafer exchange, the wafer stage 206 is moved in the direction of arrow 226 so that the pad 222 is positioned under the optical assembly 16 in place of the wafer table 204, maintaining the fluid in the gap or maintaining the size of the fluid gap. After the new wafer has been aligned, the wafer stage is moved back to its original position so that the pad 222 is removed from the gap as the second wafer is positioned under the optical assembly 16. In various embodiments, the pad 222 is disposed continuously adjacent the wafer table 204 with no gap. Vertical position and/or tilt of the wafer table 204 can be adjusted so that the wafer table surface is coplanar with the pad surface, before the wafer table 204 is moved out from under the optical assembly 16.

Maintaining the gap between the pad 222 and the optical assembly 16 is not limited to just a wafer exchange operation. The pad 222 can be large enough to maintain the immersion fluid 212 in the space between the pad 222 and the optical assembly 16 during an alignment operation or a measurement operation.

5 In those operations, a part of the area occupied by the immersion fluid 212 may be on the upper surface of the wafer table 204.

Referring to Figure 3A and 3B, a cross section and a top down view of another immersion lithography machine according to another embodiment of the present invention is shown. The lithography machine 300 includes an optical

10 assembly 16 and a stage assembly 302 that includes a wafer table 304 and a wafer stage 306. The wafer table 304 is configured to support a wafer 308 (or any other type of work piece) under the optical assembly 16. An environmental system 26, surrounding the optical assembly 16, is used to supply and remove immersion fluid 312 from the gap between the wafer 308 and the lower most

15 optical element of the optical assembly 16. A work piece exchange system 316, including a wafer loader 318 and an alignment tool 320, is configured to remove the wafer 308 on the wafer table 304 and replace it with a second wafer. This is accomplished using the wafer loader 318 to remove the wafer 308 from the wafer table. Subsequently, the second wafer (not shown) is placed onto the wafer chuck

20 318, aligned using the alignment tool 320, and then positioned under the optical assembly 16. As best illustrated in Figure 3B, a set of motors 322 are used to move the wafer assembly 302 including the wafer table 304 and wafer stage 306 in two degrees of freedom (X and Y) during operation. As noted above, the motors 322 can be any type of motors, such as linear motors, rotary motors, voice

25 coil motors, etc.

The immersion lithography machine 300 also includes an immersion fluid containment system 324 that is configured to maintain the immersion fluid 312 in the space below the optical assembly 16 while the wafer table 304 is away from under the optical assembly. The immersion fluid containment system 324

30 includes a pad 326, a motor 328, and a control system 330. The pad 326 can be positioned adjacent the optical assembly 16 and the wafer table 204. The wafer table 304 has a flat upper surface which is coplanar with a surface of the wafer 308. The pad 326 has a flat upper surface which is coplanar with the upper surface of the wafer table 304 and the wafer surface. The pad 326 is movable in

the X and Y directions using the motor 328 which is controlled by the control system 330. The motor 328 can be any type of motors as well as the motors 322. The pad 326 is positioned under the optical assembly 16 when the wafer table 304 (the wafer stage 306) is away from under the optical assembly 16. During a wafer exchange, the wafer table 304 moves away from the optical assembly 16. Simultaneously, the control system 330 directs the motor 328 to move pad 326 under the optical assembly 16, replacing the wafer table 308. The pad 326 thus retains the immersion fluid 312 within the gap under the optical assembly 16. After the new wafer has been aligned using the alignment tool 320, the wafer table 304 is repositioned under the optical assembly 16. At the same time, the control system 330 directs the motor 328 to retract the pad 326 from the gap, preventing the escape of the immersion fluid 312. In the wafer exchange operation, the control system 330 moves the wafer table 304 and the pad 326 with a small gap between the wafer table 304 and the pad 326, while the immersion fluid 312 below the optical assembly 16 moves between the wafer table 304 and the pad 326. The immersion fluid containment system 324 thus maintains the immersion fluid 312 from the gap during wafer exchange. In this embodiment, the wafer table 304 (the wafer stage 306) and the pad 326 are movable separately. Therefore, the wafer table 326 is movable freely while the immersion fluid 312 is maintained in the space between the pad 326 and the optical assembly 16. In various embodiments of the invention, the control system 330 may be a separate control system or it can be integrated into the control system used to control the motors 322 for positioning the wafer stage 302 and wafer table 304. Vertical position and/or tilt of at least one of the wafer table 304 and the pad 326 may be adjusted so that the wafer table surface is coplanar with the pad surface, before the wafer table is moved out from under the optical assembly 16. The operation, in which the wafer table 304 is away from the optical assembly 16, is not necessarily limited to a wafer exchange operation. For example, an alignment operation, a measurement operation or other operation may be executed while maintaining the immersion fluid 312 in the space between the pad 326 and the optical assembly 16.

Referring to Figure 4A and 4B, two cross sections of an immersion lithography machine are shown. The lithography machine 400 includes an optical assembly 16 and a stage assembly 402 that includes a wafer table 404 and a

wafer stage 406. The wafer table 404 is configured to support a wafer 408 (or any other type of work piece) under the optical assembly 16. An environmental system 26, surrounding the optical assembly 16, is used to supply and remove immersion fluid 412 from the gap between the wafer 408 and the lower most optical element of the optical assembly 16. A work piece exchange system 416, including a wafer loader 418 and an alignment tool 420, is configured to remove the wafer 408 on the wafer table 404 and replace it with a second wafer. This is accomplished using the wafer loader 418 to remove the wafer 408 from the wafer table 404. Subsequently, the second wafer (not shown) is placed onto the wafer chuck 418, aligned using the alignment tool 420, and then positioned under the optical assembly 16 as illustrated in the Figure 4A.

The immersion lithography machine 400 also includes an immersion fluid containment system 424 that is configured to maintain the immersion fluid 412 in the space below the optical assembly 16 while the wafer table 404 is away from under the optical assembly 16. The immersion fluid containment system 424 includes a pad 426, a first clamp 428 provided on the optical assembly 16 and a second clamp 430 provided on the wafer table 404. When the immersion fluid 412 is between the optical assembly 16 and the wafer table 404 (or the wafer 408), the pad 426 is held by the second clamp 430 in place on the wafer table 404. When the wafer table 404 is away from the optical assembly 16, for example during a wafer exchange operation, the pad 426 is detached from the wafer table 404 and held by the first clamp 428 to maintain the immersion fluid 412 between the optical assembly 16 and the pad 426. The wafer table 404 has a flat upper surface which is coplanar with a surface of the wafer 408. The pad 426 held on the wafer table 404 also has a flat upper surface which is coplanar with the upper surface of the wafer table 404 and the wafer surface. Therefore, the immersion pad 426 and wafer 408 can be moved under the optical assembly without the immersion fluid leaking. In various embodiments, the clamps 428 and 430 can be vacuum clamps, magnetic, electro-static, or mechanical.

As best illustrated in Figure 4A, the pad 426 is positioned on the wafer table 404 during exposure of the wafer 408. The second clamp 430 is used to hold the pad 426 in place on the table 404 during the wafer exposure. During a wafer exchange as illustrated in Figure 4B, the wafer table 404 is moved in the direction of arrow 432 so that the pad 426 is positioned under the optical assembly 16 in

place of the wafer 408. When this occurs, the second clamp 430 holding the pad 426 to the wafer table 404 is released while first clamp 428 clamps the pad 426 to the optical assembly 16. As a result, the immersion fluid 412 is maintained under the optical assembly while the wafer 408 is exchanged. After the new wafer has  
5 been aligned, the wafer table 404 is moved in the direction opposite arrow 432 so that the new wafer is positioned under the optical assembly. Prior to this motion, the first clamp 428 is released while the second clamp 430 again clamps the pad 426 to the wafer table 404. In this embodiment, the wafer table 404 is freely movable while the pad 426 is clamped by the first clamp 428.

10 In various embodiments, the operation, in which the pad 426 is clamped by the first clamp 428, is not limited to only a wafer exchange operation. An alignment operation, a measurement operation, or any other operation can be executed while the immersion fluid 312 is maintained in the space between the optical assembly 16 and the pad 426 clamped by the first clamp 428. Also, the  
15 clamp 428 can be provided on the frame 12 or other support member, and the clamp 430 can be provided on the wafer stage 406. The pad 426 can be held on a movable member other than the stage assembly 402.

Figure 5A and 5B are top down views of two different twin stage immersion lithography systems according to other embodiments of the present invention. For  
20 the basic structure and operation of the twin stage lithography systems, see US Patent No. 6,262,796 and US Patent No. 6,341,007. As far as is permitted, the disclosures in US Patent No. 6,262,796 and US Patent No. 6,341,007 are incorporated herein by reference. In both embodiments, a pair of wafer stages WS1 and WS2 are shown. Motors 502 are used to move or position the two  
25 stages WS1 and WS2 in the horizontal directions whereas motors 504 are used to move or position the stages WS1 and WS2 in the vertical direction. The motors 502 and 504 are used to alternatively position one stage under the optical assembly 16 while a wafer exchange and alignment is performed on the other stage. When the exposure of the wafer under the optical assembly 16 is complete,  
30 then the two stages are swapped and the above process is repeated. With either configuration, the various embodiments of the present invention for maintaining immersion fluid in the gap under the optical assembly 16 as described and illustrated above with regard to Figures 2 through 4, can be used with either twin stage arrangement. With regard the embodiment of Figure 2 for example, each

wafer stage SW1 and SW2 of either Figure 5A or 5B can be modified to include a pad 222 and a support member 224. With regard to the embodiment of Figure 3, a single pad 326, motor 328, and control system 330 could be used adjacent the optical assembly 16. The pad 326 is movable separately from the stage SW1 and SW2. During the time when stage SW1 and SW2 are to be swapped, the pad 326 is moved to under the optical assembly 16 to maintain the immersion fluid 312 below the optical assembly 16. Finally with the embodiment of Figure 4, a detachable single pad can be used. During the time when stage SW1 and SW2 are to be swapped, the pad 426 is used to maintain the immersion fluid in the gap as illustrated in Figure 4B. On the other hand during exposure, the pad is clamped onto the wafer table on the wafer stage that is being exposed. In this manner, only a single pad is needed for the two stages WS1 and WS2. Alternatively, as described below, the second stage can also be used as the pad.

Referring to Figure 6A, a top down view of a twin stage lithography machine illustrating one embodiment of practicing the present invention is shown. In this embodiment, the immersion lithography system 600 includes first stage 604 and second stage 606. The two stages are moved in the X and Y directions by motors 602. In this embodiment, the stages 604 and 606 themselves are used to contain the immersion fluid in the gap. For example as shown in the Figure, the first stage 604 is positioned under the optical assembly 16. When it is time for the work piece to be exchanged, the motors 602 are used to position the second stage 606 with a second work piece adjacent the first stage 604. With the two stages positioned side-by-side, they substantially form a continuous surface. The motors 602 are then used to move the two stages in unison so that the second stage 604 is position under the optical assembly 16 and the first stage is no longer under the optical assembly 16. Thus when the first work piece is moved away from the optical assembly 16, the immersion fluid in the gap is maintained by the second stage 606 which forms the substantially continuous surface with the first stage. In various alternative embodiments, the second stage 606 could also be a "pad" stage that contains a pad that is used to maintain the immersion liquid in the gap while a second work piece is being placed onto the first stage 604. Similarly, the motor arrangement shown in either Figure 5A or 5B could be used.

Referring to Figures 6B-6E, a series of diagrams illustrating a work piece exchange according to one embodiment of the present invention is illustrated.

Figure 6B shows a wafer on stage 604 after exposure is completed. Figure 6C shows the second stage 606 in contact (or immediately adjacent) with the first stage 604 under the optical assembly 16. Figure 6C shows a transfer taking place, i.e., the second stage 606 is positioned under the optical assembly 16. Finally, in Figure 6E, the first stage 604 is moved away from the optical assembly 16. As best illustrated in Figures 6C and 6D, the two stages 604 and 606 provide a continuous surface under the optical assembly 16 during a transfer, thus maintaining the immersion fluid in the gap. In the embodiment shown, the second stage 606 is a pad stage. This stage, however, could also be a work piece stage as noted above.

In the various embodiments described above, the pad can be made of a number of different materials, such as ceramic, metal plastic. These materials may also be coated with Teflon according to other embodiments. The size of the pad also should be sufficient to cover the area occupied by the immersion fluid. In the various embodiments described above, the surface of the last optical element of the optical assembly 16 is constantly under immersion fluid environment, preventing the formation of a fluid mark (e.g. "a water mark").

Semiconductor wafers can be fabricated using the above described systems, by the process shown generally in Figure 7A. In step 701 the work piece's function and performance characteristics are designed. Next, in step 702, a mask (reticle) having a pattern is designed according to the previous designing step, and in a parallel step 703 a wafer is made from a silicon material. The mask pattern designed in step 702 is exposed onto the wafer from step 703 in step 704 by a photolithography system described hereinabove in accordance with the present invention. In step 705 the semiconductor work piece is assembled (including the dicing process, bonding process and packaging process), finally, the work piece is then inspected in step 606.

Figure 7B illustrates a detailed flowchart example of the above-mentioned step 704 in the case of fabricating semiconductor work pieces. In Figure 7B, in step 711 (oxidation step), the wafer surface is oxidized. In step 712 (CVD step), an insulation film is formed on the wafer surface. In step 713 (electrode formation step), electrodes are formed on the wafer by vapor deposition. In step 714 (ion implantation step), ions are implanted in the wafer. The above mentioned steps



711 - 714 form the preprocessing steps for wafers during wafer processing, and selection is made at each step according to processing requirements.

At each stage of wafer processing, when the above-mentioned preprocessing steps have been completed, the following post-processing steps are implemented. During post-processing, first, in step 715 (photoresist formation step), photoresist is applied to a wafer. Next, in step 716 (exposure step), the above-mentioned exposure work piece is used to transfer the circuit pattern of a mask (reticle) to a wafer. Then in step 717 (developing step), the exposed wafer is developed, and in step 718 (etching step), parts other than residual photoresist (exposed material surface) are removed by etching. In step 719 (photoresist removal step), unnecessary photoresist remaining after etching is removed.

Multiple circuit patterns are formed by repetition of these preprocessing and post-processing steps.

While the particular lithography machines as shown and disclosed herein is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. An apparatus, comprising:
  - 2 an optical assembly configured to project an image onto a work piece;
  - 4 a stage assembly including a work piece table configured to support the work piece adjacent the optical assembly; and
  - 6 an immersion fluid system configured to substantially maintain an immersion fluid in a gap adjacent the optical assembly when the work piece
  - 8 table is moved away from the optical assembly.
2. The apparatus of claim 1, wherein the immersion fluid containment system comprises:
  - 4 a pad positioned adjacent the work piece; and
  - 6 a stage assembly mover configured to move the stage assembly such that the pad is positioned adjacent the optical assembly to maintain the immersion fluid in the gap.
3. The apparatus of claim 2, wherein the immersion fluid system further comprises a first clamp configured to hold the pad adjacent the optical assembly to maintain the immersion fluid in the gap.
4. The apparatus of claim 3, wherein the first clamp is mechanically coupled to a housing attached to the optical assembly.
5. The apparatus of claim 3, further comprising a second clamp on the stage assembly, the second clamp configured to hold the pad onto the work piece table when the work piece table is adjacent the optical assembly.
6. The apparatus of claim 3, further comprising a second clamp on the stage assembly, the second clamp configured to hold the pad onto the stage assembly when the work piece table is adjacent the optical assembly.

7. The apparatus of claim 5, wherein the first clamp is configured to  
2 clamp the pad when the work piece table is being moved away from the optical  
assembly and to release the pad when the work piece table is adjacent the optical  
4 assembly.

8. The apparatus of claim 6, wherein the second clamp is configured to  
2 clamp the pad when the work piece table is being moved away from the optical  
assembly and to release the pad when the work piece table is adjacent the  
4 optical assembly.

9. The apparatus of claim 3, wherein the clamp comprises one of the  
2 following types of clamps: vacuum, magnetic, electro-static, or mechanical.

10. The apparatus of claim 1, wherein the immersion fluid system further  
2 comprises:  
a pad positioned adjacent the optical assembly and stage assembly  
4 including the work piece table; and  
a motor, coupled to the pad, and configured to insert the pad into the  
6 gap to maintain the immersion fluid in the gap when the work piece table is  
moved away from the optical assembly.

11. The apparatus of claim 1, wherein the stage assembly further  
2 comprises a work piece stage positioned adjacent the work piece table and  
configured to move the work piece table, the work piece stage further including a  
4 pad that is configured to be inserted into the gap to maintain the immersion fluid in  
the gap when the work piece exchange system is exchanging the work piece.

12. The apparatus of claim 9, wherein the work piece stage further  
2 comprises a support member configured to support the pad adjacent the gap  
when the work piece exchange system is not exchanging the work piece and to  
4 position the pad in the gap when the work piece exchange system is exchanging  
the work piece.

13. The apparatus of claim 1, further comprising:  
2 a second stage assembly including a second work piece table  
configured to support a second work piece; and  
4 a control system configured to control the movement of the first  
stage assembly and the second stage assembly such that the two stage  
6 assemblies are alternatively positioned under the optical assembly.

14. The apparatus of claim 1, further comprising a work piece exchange  
2 system configured to remove the work piece on the work piece table and to  
replace it with a second work piece.

15. The apparatus of claim 14, wherein the work piece exchange system  
2 comprises a robot to remove the work piece and to replace it with the second work  
piece.

16. The apparatus of claim 1, further comprising an alignment tool to  
2 align the work piece.

17. The apparatus of claim 1, further comprising an environmental  
2 system configured to supply and remove immersion fluid into and from the gap.

18. The apparatus of claim 1, wherein the stage assembly includes the  
2 work piece table and a second work piece table, the work piece table and the  
second work piece table being configured to alternatively support the work piece  
4 and a second work piece adjacent the optical assembly respectively.

19. The apparatus of claim 18, wherein the immersion fluid system  
2 comprises a pad that is used to maintain the immersion fluid in the gap when  
either the work piece table or the second work piece table is moved away from the  
4 optical assembly.

20. The apparatus of claim 1, further comprising:  
2 a reticle stage configured to hold a reticle defining a pattern; and  
a projection system configured to project the pattern defined by the  
4 reticle onto the work piece through the optical assembly.
21. The apparatus of claim 1, wherein the apparatus is a lithography  
2 machine.
22. The apparatus of claim 1, wherein the work piece is one of the  
2 following types of work pieces: a semiconductor wafer, or a LCD display panel.
23. The apparatus of claim 1, wherein the immersion fluid system further  
2 comprises a second stage configured to be positioned adjacent the stage  
assembly and to form a substantially continuous surface with the stage assembly  
4 and to be moved in unison with the stage assembly when the work piece is moved  
away from the optical assembly.
24. The apparatus of claim 23, wherein the second stage includes a  
2 second work piece table configured to support a second work piece adjacent the  
optical assembly.
25. The apparatus of claim 23, wherein the second stage includes a  
2 pad.
26. An apparatus comprising:  
2 an optical assembly configured to project an image;  
a first stage assembly including a work piece table configured to  
4 support a work piece adjacent the optical assembly;  
a gap between the optical assembly and the work piece on the stage  
6 assembly, the gap being configured to be filled with an immersion fluid; and  
a second stage configured to be positioned adjacent the first stage,

8 the first stage and the second stage forming a substantially continuous  
surface such that as the first stage and the second stage are moved in  
10 unison under the optical assembly the fluid in the gap is substantially  
maintained.

27. The apparatus of claim 26, further comprising motors to move the  
2 first stage and the second stage.

28. The apparatus of claim 26, wherein the second stage is a second  
2 stage assembly including a second work piece table configured to support a  
second work piece adjacent the optical assembly when the second stage is  
4 positioned under the optical assembly.

29. The apparatus of claim 26, wherein the second stage is a pad stage  
2 configured to support a pad.

30. The apparatus of claim 2, wherein the pad is made of but is not  
2 limited to one of the following materials: plastic, metal or ceramic.

31. The apparatus of claim 30, wherein the pad is coated with Teflon.

32. The apparatus of claim 21, further comprising an illumination source  
2 including an ArF excimer laser, and wherein the immersion fluid includes water,  
and the work piece is exposed through the immersion fluid.

33. The apparatus of claim 21, wherein the immersion fluid system  
2 further comprising:  
an immersion member configured to be adjacent the optical  
4 assembly to maintain the immersion fluid in the gap between the optical  
assembly and the immersion member.

2 34. The apparatus of claim 33, wherein the immersion member includes a pad.

2 35. The apparatus of claim 33, wherein the immersion fluid system includes a moving system configured to move the immersion member to/from the gap adjacent the optical assembly.

2 36. The apparatus of claim 35, wherein the moving system includes a part of the stage assembly.

2 37. The apparatus of claim 36, wherein the immersion member is attachable to the stage assembly and detachable from the stage assembly.

2 38. The apparatus of claim 35, wherein the moving system moves the immersion member separately from the work piece table.

2 39. The apparatus of claim 33, wherein the immersion member is clamped relative to the optical assembly in order to maintain the immersion fluid in the gap between the optical assembly and the immersion member.

2 40. The apparatus of claim 33, wherein the work-piece table is movable separately from the immersion member, while the immersion fluid is maintained in the gap between the optical assembly and the immersion member.

2 41. The apparatus of claim 33, wherein work piece exchange operation is executed, while the immersion fluid is maintained in the gap between the optical assembly and the immersion member.

2 42. The apparatus of claim 33, wherein the immersion member has a surface which sheds the immersion fluid.

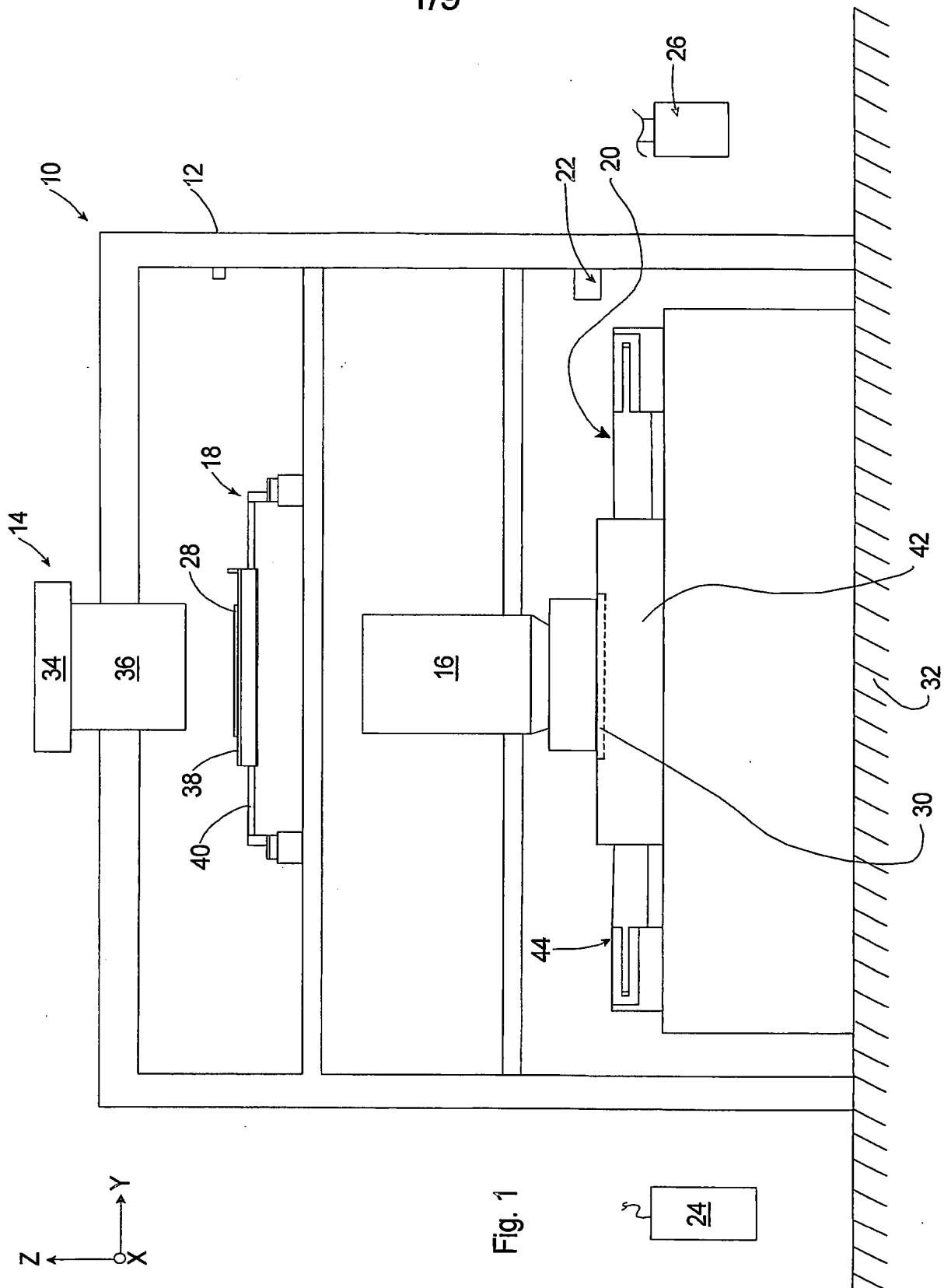
43. The apparatus of claim 42, wherein the surface of the immersion  
2 member is coated with Teflon.

44. The apparatus of claim 42, wherein the immersion member is made  
2 of one of the following materials: plastic, metal or ceramic.

45. A micro-device manufacturing method using the apparatus of claim  
2 33.



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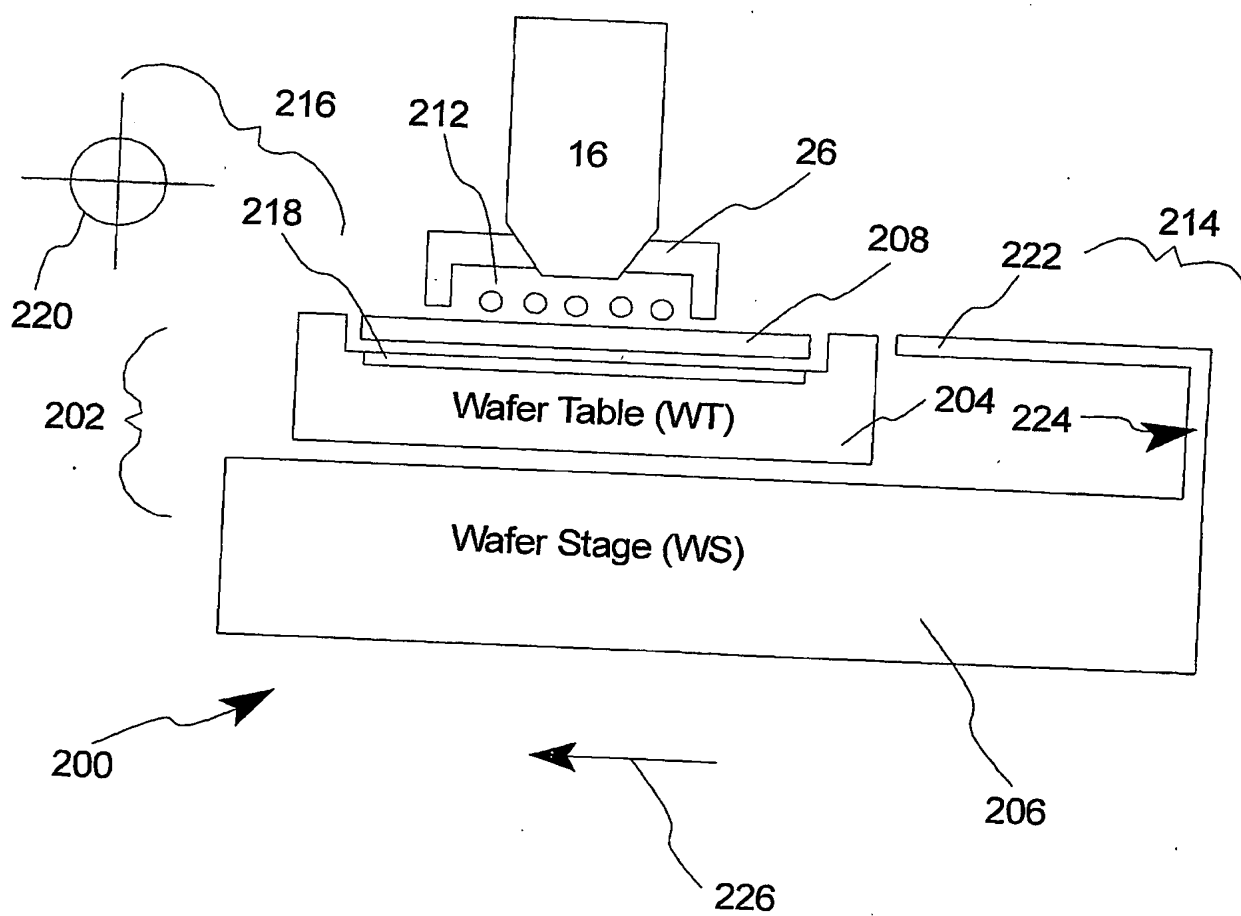


Fig. 2

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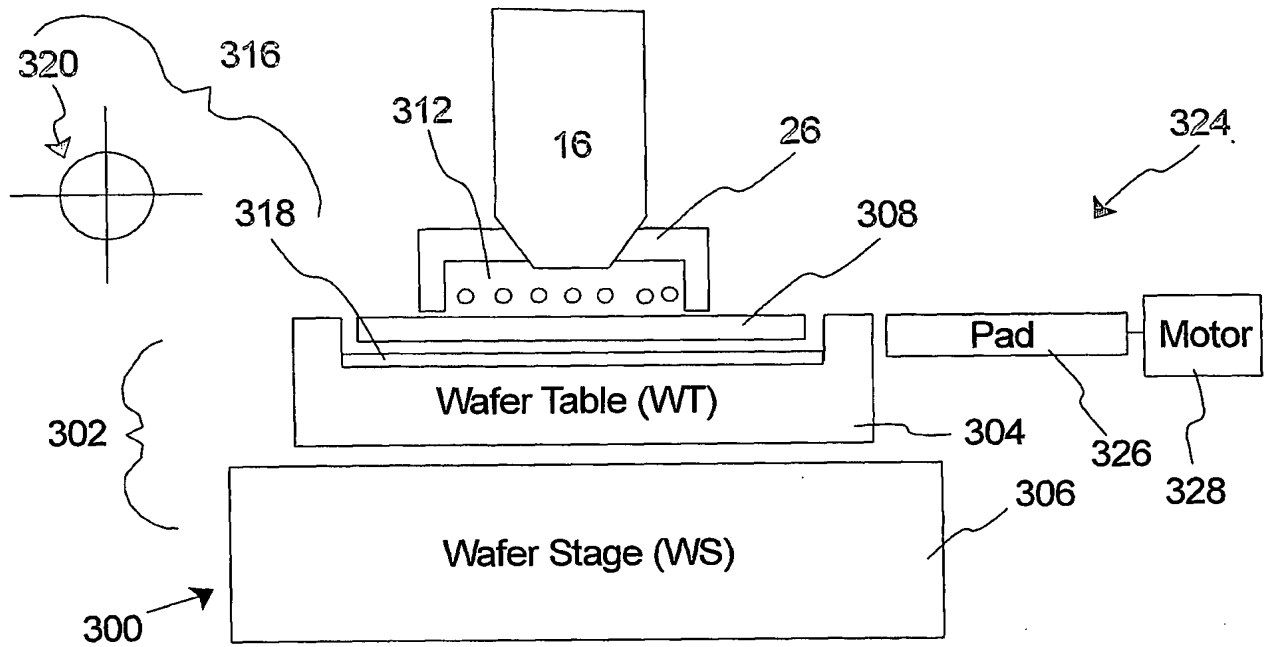


Fig. 3A

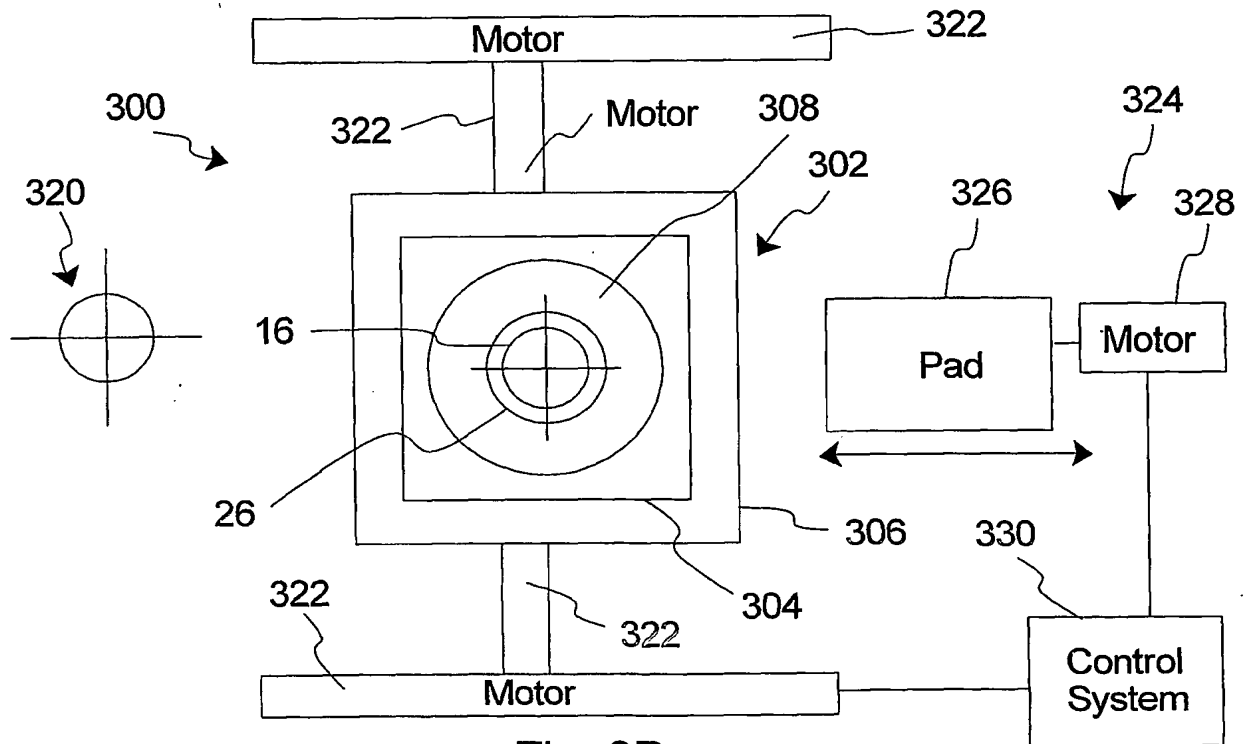


Fig. 3B

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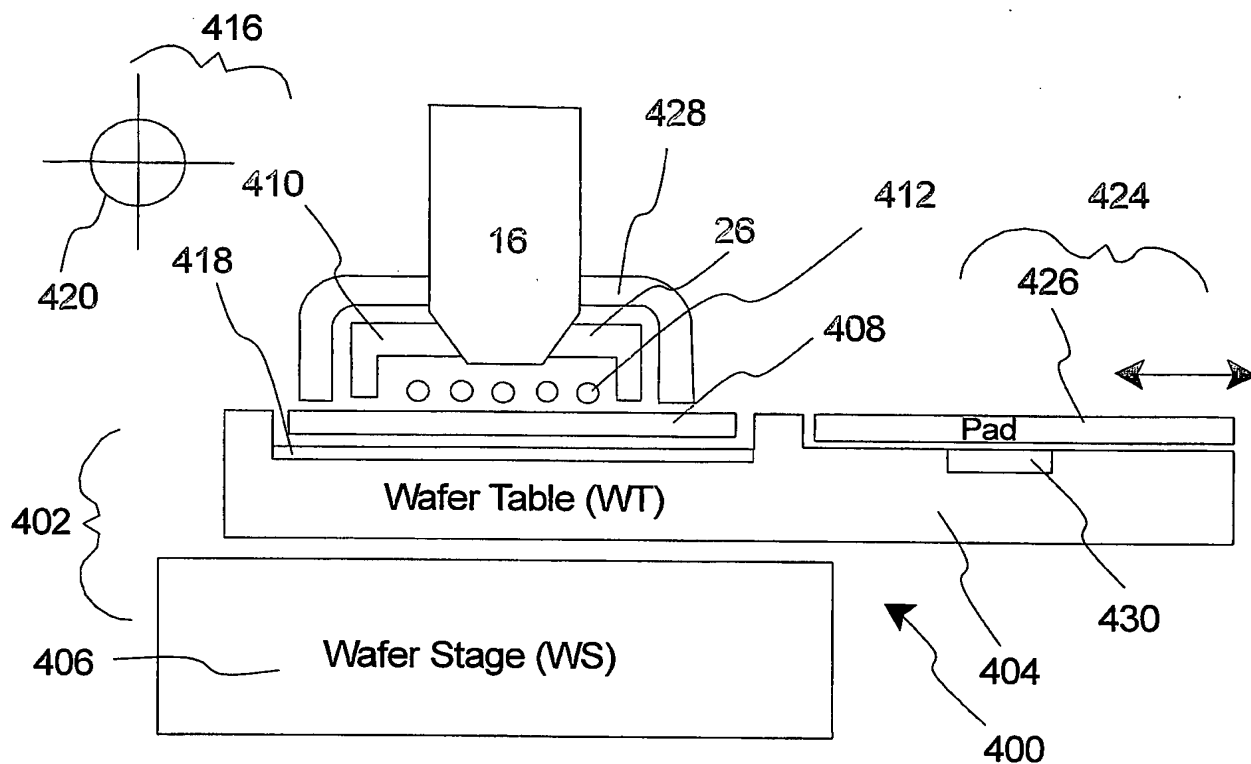


Fig. 4A

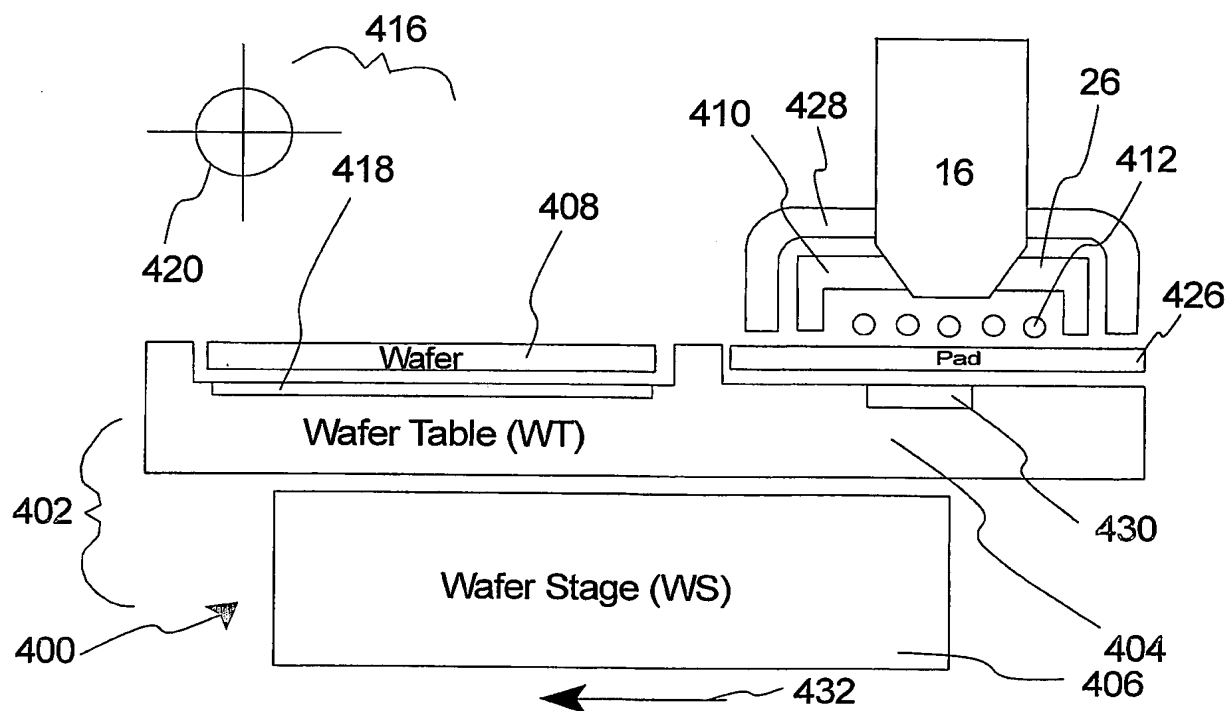


Fig. 4B

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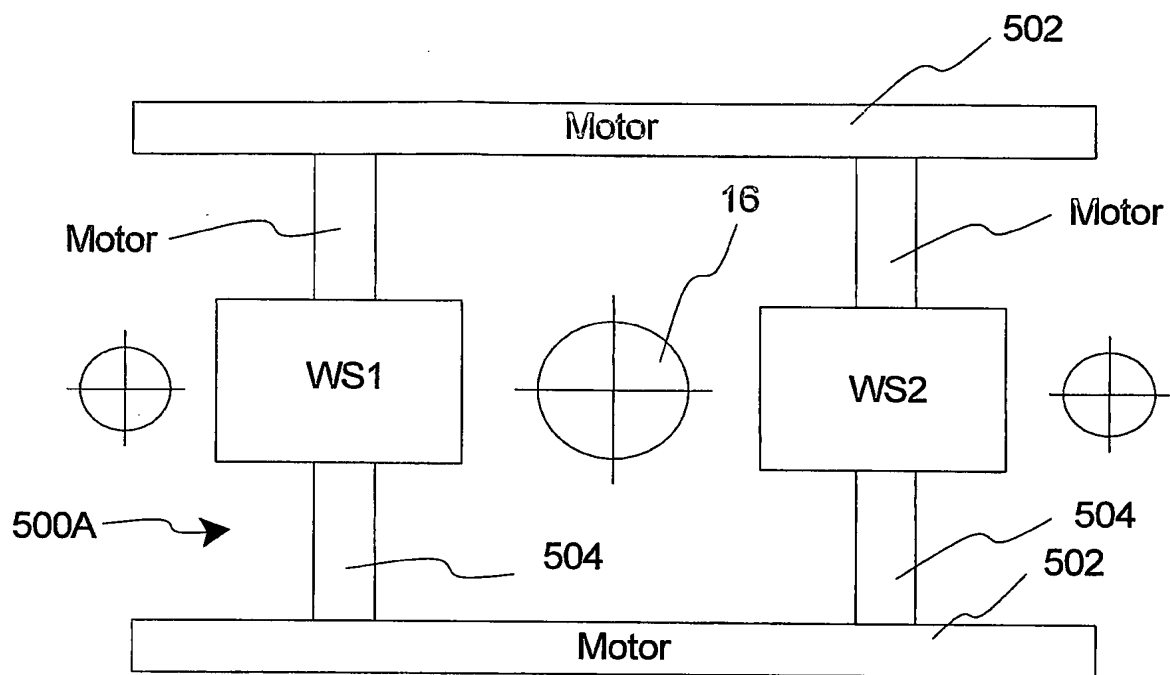


Fig. 5A

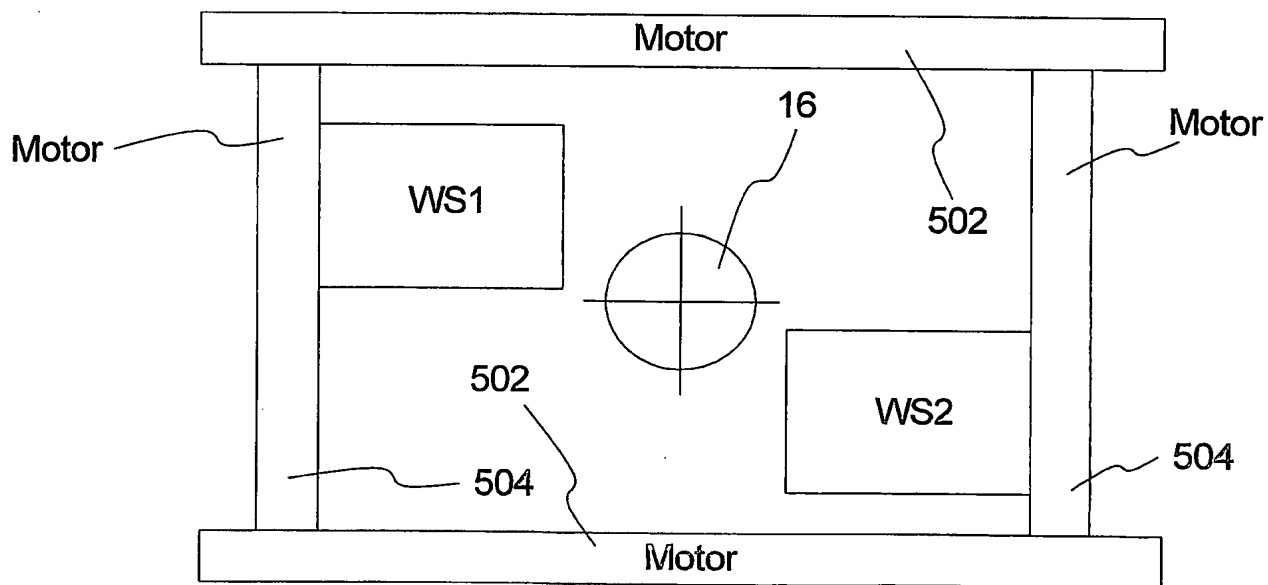


Fig. 5B

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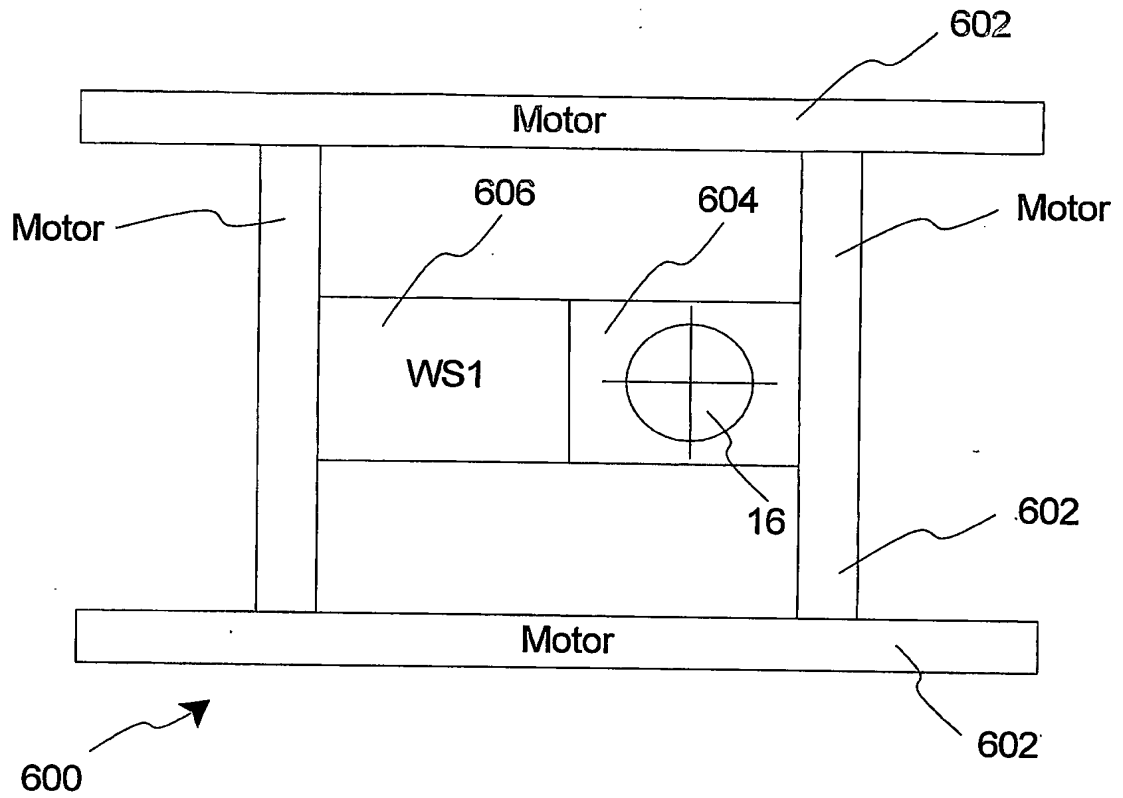


Fig. 6A

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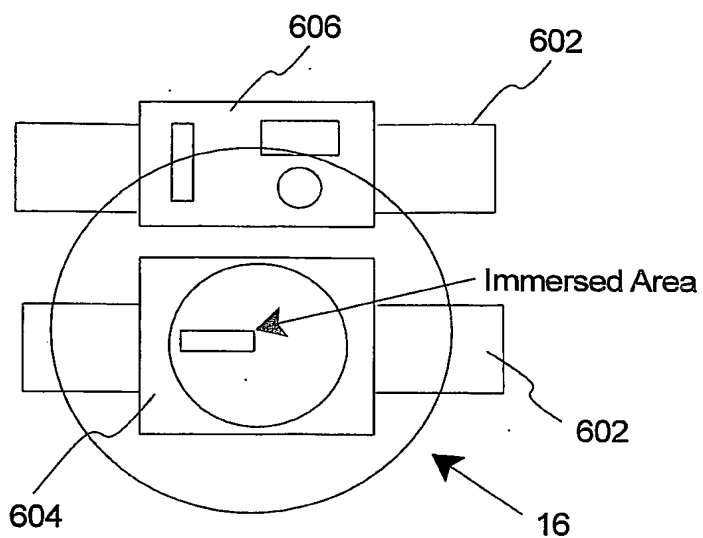


Fig. 6B

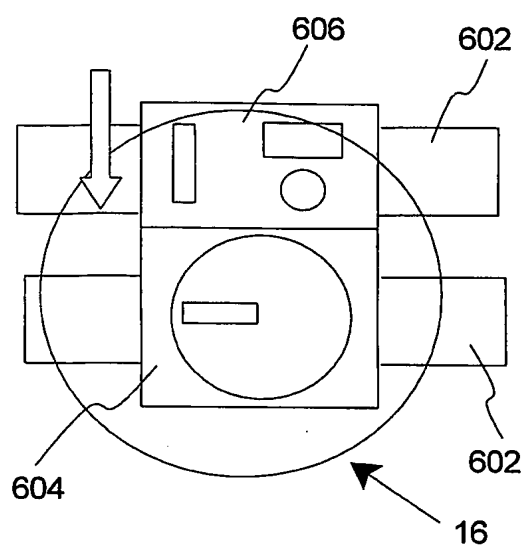


Fig. 6C

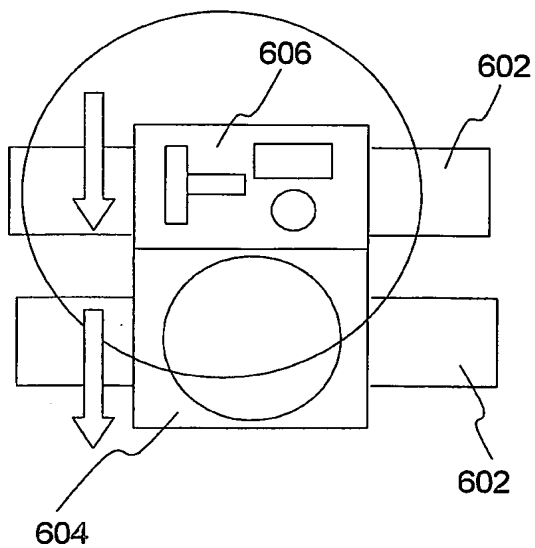


Fig. 6D

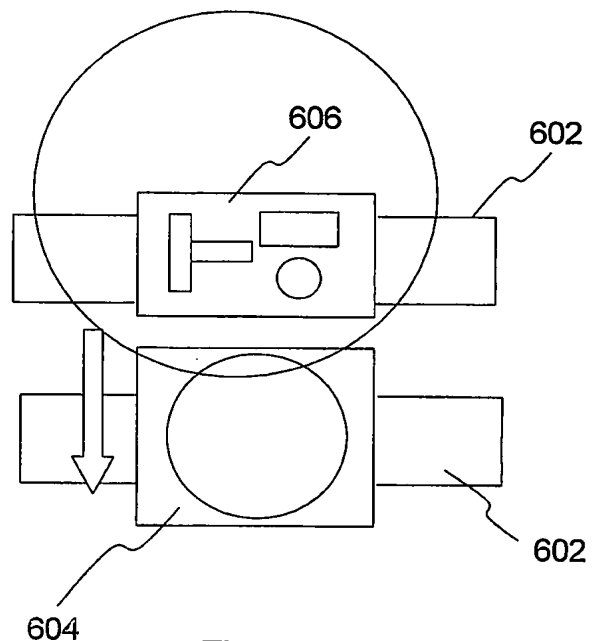


Fig. 6E

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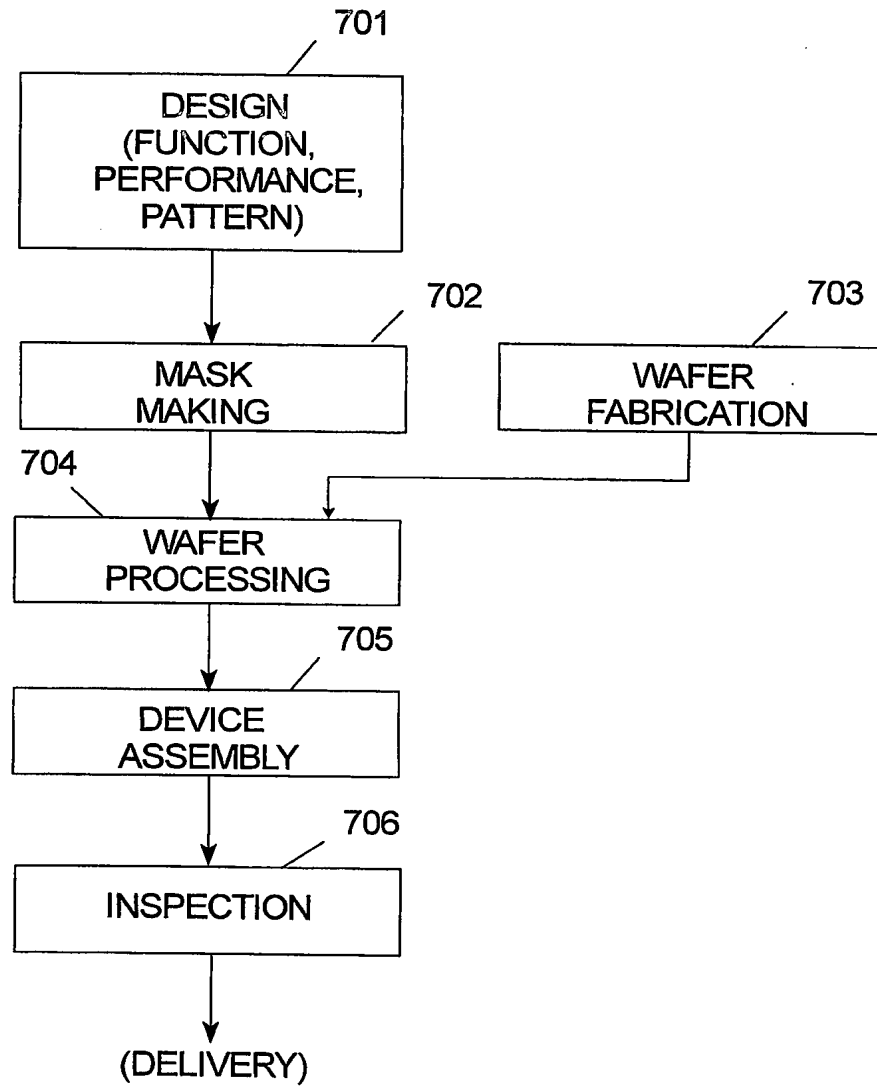


Fig. 7A



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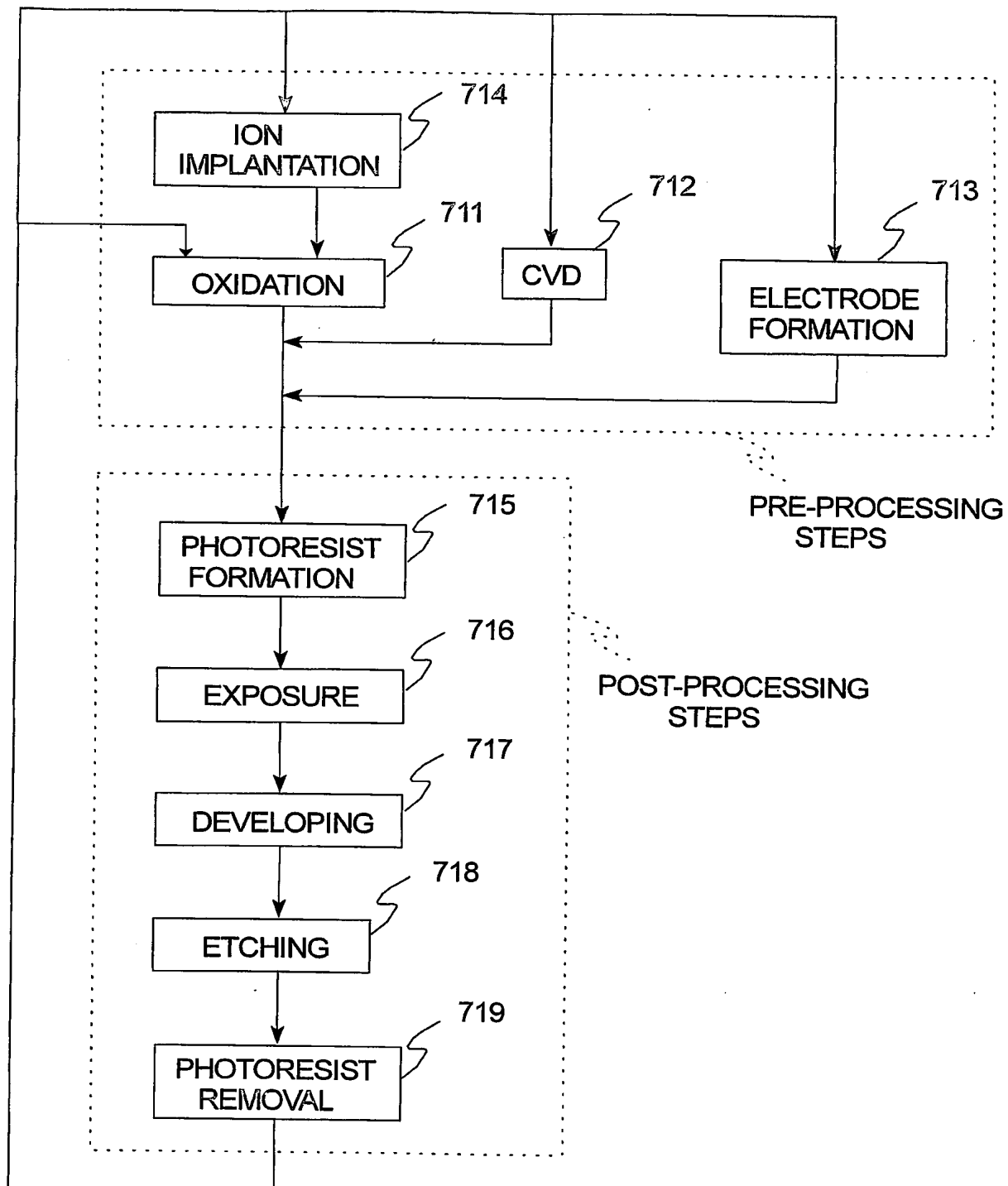


Fig. 7B

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**Declaration under Rule 4.17:**

— of inventorship (Rule 4.17(iv)) for US only

**Published:**

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— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

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21 April 2005

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MAINTAINING IMMERSION FLUID UNDER A LITHOGRAPHIC PROJECTION LENS

(57) Abstract: An apparatus and method for maintaining immersion fluid (212) in the gap adjacent the projection lens (16) during the exchange of a work piece (208) in a lithography machine (10) is disclosed. The apparatus and method includes an optical assembly (16) configured to project an image onto a work piece (208) and a stage assembly (202) including a work piece table (204) configured to support the work piece (208) adjacent the optical assembly (16). An environmental system (26) is provided to supply and remove an immersion fluid (212) from a gap between the optical assembly (16) and the work piece (208) on the stage assembly (202). After exposure of the work piece (208) is complete, an exchange system (216) removes the work piece (208) and replaces it with a second work piece. An immersion fluid containment system (214) is provided to maintain the immersion liquid (212) in the gap during removal of the first work piece (208) and replacement with the second work piece.

WO 2004/090577 A3

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB04/01259

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G03B 27/32, 27/42, 27/58

US CL : 355/53, 72, 77

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 355/53, 72, 77, 55; 356/399, 400

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
(355/53,55,72,77.ccls. or 356/399,400.ccls.) and immersion

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 10-303114 A (USHIDA ET AL) 13 November 1998 (13.11.1998) See figures 1 and 5 and paragraphs # 15, 17-19, 24, and 41 of translation	1, 14-17, 20-22, 32
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A		2-13, 18, 19, 23-31, 33-45
A	JP 06-124873 A (KAZUO) 06 May 1994 (06.05.1994) See figures 1 and 11.	1-45
A	JP-10-340846 A (KUDO) 22 December 1998 (22.12.1998) See figures 1 and 2	1-45
A	US 5,610,683 A (TAKAHASHI) 11 March 1997 (11.03.1997) See figures 1 and 2	1-45
A	US 5,825,043 A (SUWA) 20 October 1998 (20.10.1998) See figures 9 and 10.	1-45
A	US 4,509,852 A (TABARELLI ET AL) 09 April 1985 (09.04.1985) See figures 3 and 4	1-45

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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"T"

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document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&"

document member of the same patent family

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*J. Whitehead*  
For

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB04/01259

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐

The additional search fees were accompanied by the applicant's protest.

☐

No protest accompanied the payment of additional search fees.